Extraction of Circle of Willis from 2D Magnetic Resonance Angiograms

Sarbani Datta[1] and Dr. Monisha Chakraborty[*, 1]
[1] Student, School of Bio-Science and Engineering, Jadavpur University, Kolkata, India
[1]Email: sarbanidatta.ju@gmail.com
[*, 1] Assistant Professor, School of Bio-Science and Engineering, Jadavpur University, Kolkata, India
[*, 1]Email: monishack@school.jdvu.ac.in

***Abstract*—Magnetic resonance angiogram is a way to study cerebrovascular structures. It helps to obtain information regarding blood flow in a non-invasive fashion. Magnetic resonance angiograms are examined basically for detection of vascular pathologies, neurosurgery planning, and vascular landmark detection. In certain cases it becomes complicated for the doctors to assess the cerebral vessels or Circle of Willis from the two-dimensional (2D) brain magnetic resonance angiograms. In this paper an attempt has been made to extract the Circle of Willis from 2D magnetic resonance angiograms, so as to overcome such difficulties. The proposed method pre-processes the magnetic resonance angiograms and subsequently extracts the Circle of Willis. The extraction has been done by color-based segmentation using K-means clustering algorithm. As the developed method successfully extracts the vasculature from the brain magnetic resonance angiograms, therefore it will help the doctors for diagnosis and serve as a step in the prevention of stroke. The algorithms are developed on MATLAB 7.6.0 (R2008a) programming platform.**

***Index Terms*—Magnetic resonance angiogram, Circle of Willis, pre-process, color-base segmentation, K-means clustering**

I. Introduction

Magnetic resonance angiography (MRA) is a way to study vascular structures. Segmentation of vessels from magnetic resonance angiogram can be a very useful computer aided diagnosis (CAD) tool [1]. MRA images are usually obtained on two-dimensional (2D) maximum intensity projections (MIPs), which are useful because the overall shapes and paths of the vessels become visible [2]. However, the images show poor visualization of blood vessels [3]. Hence, solution is needed to extract vessels for better visualization. Many attempts have been made for sophisticated solutions to extract vasculature from 3D MRA images [4, 5]. The quality of such images is at a high level [6]. Our research uses 2D brain magnetic resonance angiogram to determine functional information. Two-dimensional MRA images have been used to determine the stenosis of the brain. The arteries inside the skull get blocked by plaque which leads to cerebral artery stenosis [7]. Blocked cerebral arteries are much harder for a surgeon to get to. Without treatment the stenosis may lead to transient ischemic attacks or stroke [8].

[*, 1] Corresponding Author

Segmentation of the vascular system from magnetic resonance angiograms is a challenging task. Human cerebrovascular is important in neurosurgery and neurological study. Vascular diseases such as stenosis, aneurysm and vascular malformation are the leading cause of brain stroke and disability. An accurate segmentation of the vascular system is needed to detect these diseases and hence may prevent invasive treatments. The extraction of cerebral vessels or Circle of Willis from the brain angiogram would make the doctors do their job in a much easier fashion [9]. There are numerous algorithms for cerebral vessel extraction, but the limitations lie in the visualization from two-dimensional MRA images.

In this paper we proposed a pre-processing algorithm for image enhancement. This result an improvement in the contrast of the two-dimensional MRA images and consequently the Circle of Willis has been found to be significant. So, pre-processing can be considered as a necessary step for better image enhancement. This algorithm proved to be efficient for extracting cerebral vessels or Circle of Willis with color-based segmentation method. The present work is to visualize cerebral vessels or Circle of Willis stridently, to assist the doctors for identification of the disorder.

Segmentation is a challenging task in medical image analysis and classification for radiological evaluation or computer-aided diagnosis [10]. Basically, image segmentation methods can be classified into three categories: edge-based methods, region-based methods [11], and pixel-based methods. K-means clustering is a technique which based on pixel-based methods. K-means clustering is simple and the computational complexity is relatively low compared with other region-based or edge-based methods. The application is more practicable. Furthermore, K-means clustering is appropriate for biomedical image segmentation as the number of clusters is usually known for images of particular regions of the human anatomy [12]. Many researchers have proposed related research into K-means clustering segmentation [12, 13]. The improvements achieved by [12, 13] have been remarkable, but more computational complexity and extra software functionality are required.

In this work, pre-processing algorithm not only served for image enhancement but also proved to be an important step in tracing cerebral vessels or Circle of Willis from two-dimensional MRA images. The pixel-based segmentation algorithm carefully selects the Circle of Willis from the pre-

DOI: 01.IJIT.02.01.547

processed image as a clustering feature. Low computation aspect has been maintained. Hence, color-based K-means clustering segmentation on pre-processed magnetic resonance angiography (MRA) images for tracing cerebral vessels or Circle of Willis has maintained the efficiency. The experimental result that extracts the clustering feature confirms that the proposed method will help the doctors for treatment planning.

II. Methodology

A. Pre-processing Technique

Histogram equalization is a spatial domain image enhancement technique that modifies the distribution of the pixels to become more evenly distributed over the available pixel range [14]. In histogram processing, a histogram displays the distribution of the pixel intensity values, mimicking the probability density function (PDF) for a continuous function. An image that has a uniform PDF will have pixel values at all valid intensities. Therefore, it will show a high contrast image. Histogram equalization creates a uniform PDF or histogram [15]. This can be accomplished by performing a global equalization that considers all the pixels in the entire image or a local equalization that segments the image into regions. Subtraction images may also cause enhancement of certain regions of an image. In contrast enhanced MRA, a mask image is used and subtracted from a contrast enhanced image to boost up the contrast [16].

B. Pixel-based Segmentation

K-means is an extensively used clustering algorithm to partition data into *k* clusters [12]. Clustering is the process for grouping data points with similar feature vectors into a single cluster and for grouping data points with dissimilar feature vectors into different clusters. Let the feature vectors derived from *l* clustered data be X= (x_i |*i*=1,2,…,*l*). The generalized algorithm initiates k cluster centroids C=(c_j |*j*=1,2,…,*k*) by randomly selecting k feature vectors from X. Later, the feature vectors are grouped into k clusters using a selected distance measure such as Euclidean distance as in (1) so that

$$d = \|x_i - c_j\|. \quad (1)$$

The next step is to recompute the cluster centroids based on their group members and then regroup the feature vectors according to the new cluster centroids. The clustering procedure stops only when all cluster centroids tend to converge [12, 13]. The block diagram of our developed algorithm has been shown in Fig. 1. The input brain magnetic resonance angiograms are taken from the websites e.g. cedars-sinai.edu, sciencephoto.com, elsevierimages.com, springerimages.com, and imaging.consult.com.

The algorithms are developed on MATLAB version 7.6.0(R2008a) in Microsoft Windows XP operating system, with the processor 2.16GHz and 1.96GB of RAM.

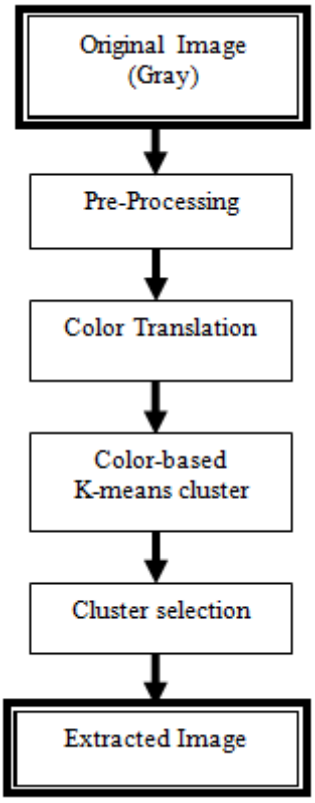

Figure 1. System Block Diagram

III. Results and discussion

Fifteen brain magnetic resonance angiograms (498x465 resolutions) were used to evaluate the proposed algorithm. Initially histogram equalization technique is performed. The original and the histogram equalized images were then converted to double precision images in order to perform the subtraction operation. Subtraction image was obtained by subtracting the original image from the histogram equalized image. Finally to get the pre-processed image, the subtracted image was complemented as shown in Fig. 3. Histogram equalization takes advantage of the neglected pixel values and provides better definition and more information for the doctors. Subtracted images boost up the result. Further, complement of the subtracted images provides a better means to assess the Circle of Willis.

Color-based segmentation on the processed image has been shown in Fig. 4. In this proposed method, we converted the pre-processed gray-level brain MRA image into RGB color image first. The RGB color image was then coarsely represented using 25 bins. Coarse representation used the spatial information from a histogram based windowing process.

K-means was used to cluster the coarse image data. In the segmented images *k*=6 was considered. The color-based K-means clustered images were further processed in order to extract the feature from the image, as shown in Fig. 5.

As seen in Fig. 4, the Circle of Willis was been detected significantly. The experimental result as in Fig. 5 will help the doctors to identify vascular disease from its location.

DOI: 01.IJIT.02.01.547

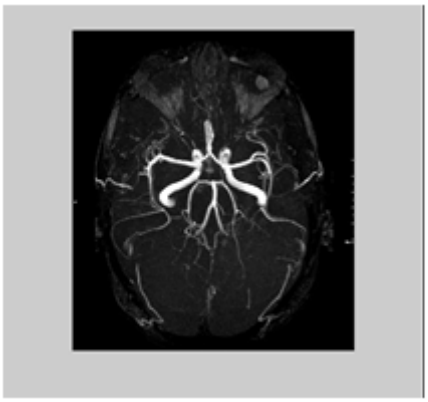

Figure 2. Original Image

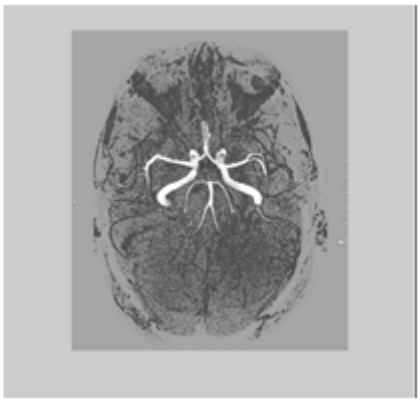

Figure 3. Pre-Processed Image

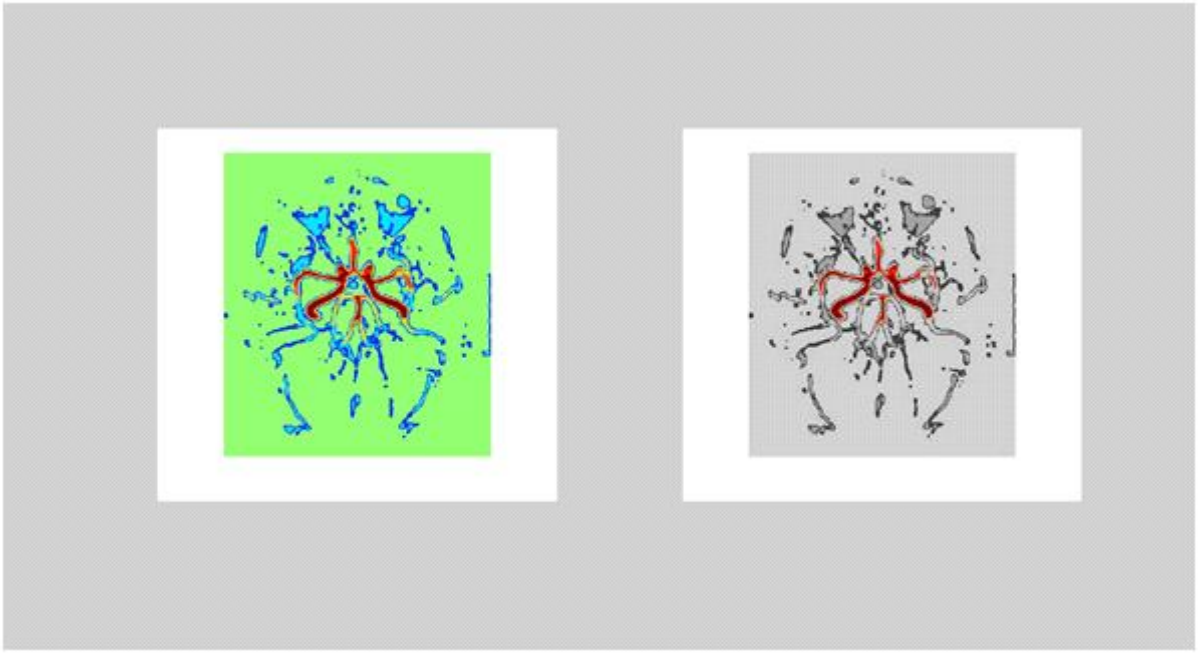

Figure 4. Color-based K-means clustering segmentation

Figure 5. Extraction of Circle of Willis

IV. Conclusions

In this paper color-based segmentation using K-means clustering for extracting Circle of Willis from brain magnetic resonance angiogram is proposed. Pre-processing on MRA image and color-based segmentation both show encouraging results. The final stage of the proposed method that extracts the clustering feature provides good segmentation performance. The present work combines color translation, color-based K-means clustering and feature extraction, thus making it efficient and easy to implement for the doctors to diagnose the Circle of Willis as well as cerebral vessels in a better way by reducing the subjectivity and miss rate in magnetic resonance angiography (MRA) images and thereby will enhance the vascular disease detection accuracy in less time.

Acknowledgment

We would like to express our sincere thanks and deepest gratitude to all the members of the websites e.g. cedars-sinai.edu, dedicatedimaging.com and springerimages.com, who provided the valuable images of normal and abnormal brain angiograms in their websites and without these images this work would not have been possible.

References

[1] N.Passat, C.Ronse, J.Baruthio, J.P.Armspach, and C.Maillot, "Magnetic resonance angiography: from anatomical knowledge modeling to vessel segmentation," *Medical Image Analysis*, pp.259-274, 2006.

[2] M.M.Orkisz, C.Bresson, I.E.Magnin, O.Champin, and P.C.Douek, "Improved vessel visualization in MR angiography by nonlinear anisotropic filtering," *Magnetic Resonance in Medicine*, vol.37, pp.914–919, 1997.

[3] P.J.Yim, G.Boudewijn, C.Vasbiner, V.B.Ho, and P.L.Choyke, "Isosurfaces as deformable models for magnetic resonance angiography," *IEEE Trans. on Medical Imaging*, vol. 22, pp. 875–881, 2003.

[4] P.Yan and A.A.Kassim, "MRA image segmentation with capillary active contour," *International Conf. on Medical Image Computing and Computer Assisted Intervention*, vol. 1, pp. 51-58, 2005.

DOI: 01.IJIT.02.01.547

[5] O.Wink, W.J.Nissen, and M.A.Viergever, "Fast delineation and visualization of vessels in 3-D angiographic images," *IEEE Trans. on Medical Imaging*, vol. 19, pp. 337–346, 2000.
[6] D.G.Nishimura, A.Macovski, and J.M.Pauly, "Magneticresonance angiography," *IEEE Trans. Med. Imag*., vol.23, no.12, pp.140-151, September 1986.
[7] S.K.Bhattacharji, E.C.Hutchinson, and A.J.McCall, "Stenosis and occlusion of vessels in cerebral infarction," *British Medical Journal*, pp.270-274, July 1967.
[8] Dr. W.LUI, "Management of intracranial cerebral arterial stenosis," *Medical Bulletin*, vol.16, no.2, February 2011.
[9] M.J.Hartkamp and J.Grond, "Investigation of the Circle of Willis using MR angiography," *Medicamundi*, vol.44, March 2000.
[10] M.Bhagwat, R.K.Krishna, and V.E.Pise, "Image segmentation by improved watershed transformation in programming environment MATLAB," *Int. J. of Computer Science and Communication,* vol. 1, pp. 171–174, 2010.
[11] A.C.S.Chung and J.A.Noble, "Vascular segmentation of phase contrast magnetic resonance angiograms based on statistical mixture modeling and local phase coherence," *IEEE Trans. on Medical Imaging*, vol. 23, pp. 1490–1507, December 2004.
[12] C.S.Tsai and C.C.Chang, "An improvement to image segment based on human visual system for object-based coding," *Fundamenta Informaticae*, vol. 58, pp. 167–178, 2004.
[13] C.W.Chen, J.Luo, and K.J.Parker, "Image segmentation via adaptive K-mean clustering and knowledge-based morphological operations with biomedical applications," *IEEE Trans. on Medical Imaging*, vol. 7, pp. 1673–1683, 1998.
[14] R. C. Gonzalez and R. E. Woods, Digital Image Processing, Prentice Hall, pp. 711-791, (2001).
[15] Y.H.Hu, ECE 533 Image Processing Lecture Notes: Image Enhancement by Modifying Gray Scale of Individual Pixels, 2002-2003.
[16] M.Prince, T.M.Grist, and J.F.Debatin, 3D Contrast MR Angiography, Springer-Verlag, NY, 1999.

DOI: 01.IJIT.02.01.547